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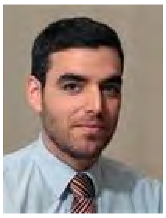


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1. Introduction and Scope

The Green Optical Communication Networks Workshop 2015, in conjunction with the CLEO Pacific Rim 2015 in Busan, Korea, was held at the Korean Advanced Institute of Science and Technology (KAIST) in Daejeon, Korean, to study and promote green technologies in the area of optical communications. Topics under discussion included green digital signal processing techniques for high-capacity networks, low consumption photonic integrated devices, pre-distortion techniques to increase transmission reach, novel WDM-PON access networks, among others. The Workshop was organized by Prof. Kevin Rhee and Prof. Yun Chung, from KAIST, and A/Prof. J.J. Vegas Olmos, from the Technical University of Denmark. The speakers originated mainly from KAIST, along with the Electronics and Telecommunications Research Institute (ETRI), Korea, and the National Institute of Information and Communications Technology (NICT), Japan. The workshop included oral presentations and two poster sessions.

Fig. 1 Presentation by NICT on green digital signal processing, clean room visit and group picture

2. Relevance of the Workshop

The power consumption of electronic routers is increasing very quickly with traffic, and traffic is growing exponentially. Moreover, the power dissipation of VLSI technologies does not improve as expected in Moore's Law [1]. Photonic technologies are alleviating these challenges, and so far they have been able to reduce the energy per bit in point-to-point optical links. However, the energy per second per user is increasing due to an increase in the bits per second per user. In other words, the per-user bandwidth demand increase dominates over the energy per bit reduction, leading to an overall increase in network energy consumption. This increase in the per-user bandwidth may be due to novel applications in which each user forms a cloud of data which needs to be accessible anytime-anywhere.

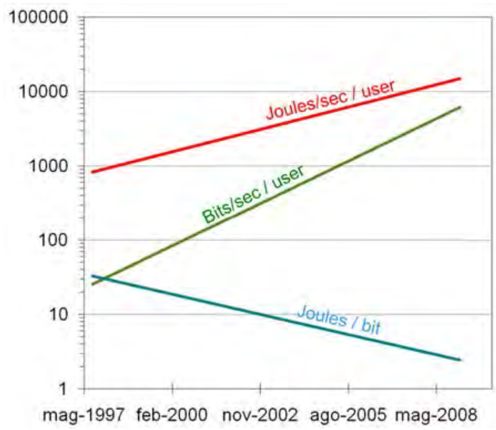

Fig. 2 Evolution of the total power consumption per user, energy per bit and bandwidth per user [1]

From a holistic point of view, this increase in energy per second per user needs to be addressed as the world faces some uncertainties on the global energy supply, as shown in Fig. 3, and renewable energy sources are not yet mature to overtake traditional fossil fuel sources. Therefore, energy efficiency is fundamental in order to meet the challenges of the following years.

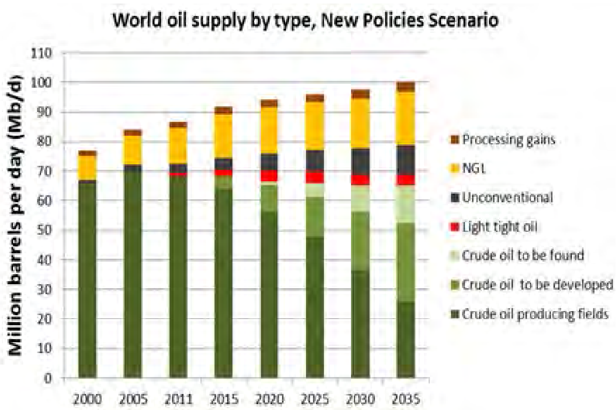

Fig. 3 International Energy Agency (IEA) estimated world oil supply [2]

3. Photonic Devices

Photonic devices enable system functionalities that are difficult to implement with traditional solid state technologies. This area of development requires a strong cooperative design among different fields: physics, materials and integration engineering. There is a clear consensus that silicon photonics is a potentially disruptive technology in the telecommunications arena and also other areas such as biophotonics, sensing, and metrology. However, the main challenge is not the development of technologies, but rather to find an application that can drive volume and push costs down. Research areas identified during the workshop are:

- Sub-wavelength scale integrated photonics.
- Development of cost-effective packaging techniques.
- Hybrid integration of silicon photonics with III/V.
- Increase effective bandwidth of silicon modulators.

4. Digital Signal Processing

Digital signal processing (DSP) is a fundamental technology of current and future optical communication networks [3]. However, current optical networks are optimized for transmission performance with little consideration about energy efficiency. Fig. 4 shows the relative energy consumption of each DSP stage in current generation DSP ASICs for optical networks. Future networks may require a holistic redesign to tackle energy efficiency [1]. For example, one such scheme may be the introduction of self-homodyne transmission in multicore fibers (MCFs) developed at NICT [5]. In this scheme, the laser used in the transmitter is propagated unmodulated in one of the MCF cores to be used as local oscillator at the receiver. This enables a reduction of the phase noise and may lead to energy savings due to joint-DSP shared resources among different MCF cores.

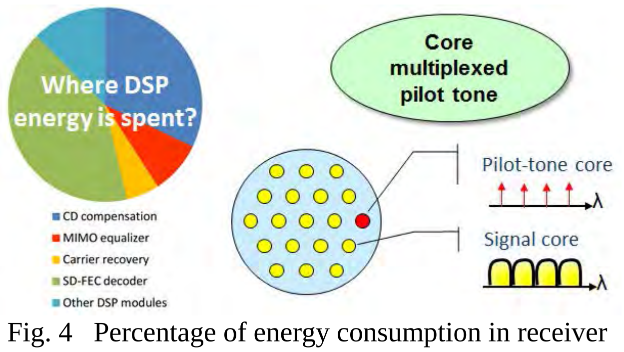

Fig. 4 Percentage of energy consumption in receiver ASIC per DSP stage, and utilization of multi-core fibers to ease DSP functions (i.e., self-homodyne MCF distribution of pilot-tones [5])

For the next generation of energy efficient DSP in optical networks, the following points were devised during the workshop:

- Network energy consumption should be a function of network utilization. Flexible, rate-adaptive transceivers, including flexible DSP blocks, are the main target to implement energy saving policies.
- Novel FEC algorithms and FEC ASIC implementations are key to reduce the power consumption.
- Multi-core fibers enable novel architectures which may simplify the DSP processes and consequently improve the energy consumption.
- MCF may be used to trade bandwidth (spatial redundancy) for energy consumption. Additional research is needed to identify new modulation formats and transmission paradigms in MCF to optimize this trade-off.

5. Systems and Architectures

Power consumption in terms of energy per second per user increases drastically in access networks, specifically in edge nodes and the last mile [6]. This is the reason novel architectures, systems, modulation formats and a holistic combination of them all are under study. Wireless systems, for example, are solely supported by optical networks; there is a trend in employing radio-over-fiber technologies for mobile back-haul/front-haul. Radio-over-fiber for access in the millimeter wave regime is a mayor research trend since this architectures offer high-density, which in turn offers the possibility of re-using frequency bands, reduce the launched RF power and improve the energy consumption. Areas identified in the workshop were:

- mmW communications for mobile back-haul using >70 GHz, including low-terahertz.
- mmW communications for end users based on MIMO techniques, low-power radiation and high capacity.

6. Summary

The Green Optical Communication Networks Workshop 2015, co-allocated with CLEO-PR 2015, was successfully closed. Main topics of research were identified in the field of photonic communications; energy efficiency is a main aspect, which requires co-design between devices, systems and architectures to effectively optimize the energy expenditures. Main research challenges can be found in novel photonic devices, DSP algorithms, multi-core fiber systems, and new optical access systems to provide more bandwidth with less energy to end users.

7. References

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